Surgeon specialty and provider volumes are related to outcome of intact abdominal aortic aneurysm repair in the United States

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Objective: **This study was undertaken to determine the relative importance of surgeon specialty, hospital volume, and surgeon volume on outcome after abdominal aortic aneurysm (AAA) repair.**
Methods: **Data were reviewed for 3912 patients undergoing AAA repair in the Nationwide Inpatient Sample during 1997. In-hospital mortality was compared between high-volume hospitals and low-volume hospitals and between high-volume surgeons and low-volume surgeons. High-volume hospitals performed more than 35 AAA repairs per year, and high-volume surgeons performed more than 10 AAA repairs per year. Vascular, cardiac, and general surgery specialization was identified by analysis of other procedures performed by each surgeon.**
Results: **Overall, AAA repair mortality was 4.2%, and was lower at high-volume hospitals (3.0%) than at low-volume hospitals (5.5%) (*P* < .001). Lowest mortality was associated with operations performed by vascular surgeons (2.2%) compared with cardiac surgeons (4.0%) and general surgeons (5.5%) (*P* < .001). Mortality rates were also lower for high-volume hospitals (2.5%) compared with low-volume hospitals (5.6%) (*P* < .001). In a risk-adjusted analysis, high-volume hospital, vascular surgery specialty, and high-volume surgeon were all independently associated with lower risk of in-hospital mortality. In this analysis, risk reduction was 30% for high-volume hospitals (95% confidence interval [CI], 2%-51%; *P* < .05) and 40% for surgery by a high-volume surgeon (95% CI, 12%-60%; *P* = .01). AAA repair by general surgeons compared with vascular surgeons was associated with 76% greater risk for death (95% CI, 10%-190%; *P* = .02). No significant difference in mortality was found between cardiac and vascular surgeons.**
Conclusions: **High surgeon volume and hospital volume of AAA repair were both associated with lower mortality compared with low-volume providers. Increased specialization in vascular surgery was associated with markedly decreased mortality independent of AAA repair volume. Health policy in support of selective referral for AAA repair should consider surgical specialization in addition to provider volume thresholds. (J Vasc Surg 2003;38:739-44.)**

Operative repair of an intact abdominal aortic aneurysm (AAA) is a complex surgical procedure associated with considerable risk for postoperative morbidity and mortality.[1-3] AAA repair is performed in a variety of hospitals, with outcome that is not uniform. Some outcome differences are related to hospital procedural volume.[3-9] In a climate of increasing provider accountability, health care policy efforts have recently been focused on concentrating high-risk surgical procedures, such as AAA repair, in medical centers with better outcome.[10-12]

Several surgical procedures result in superior outcome when performed at high-volume centers, and more technically complex procedures demonstrate a stronger relationship with volume.[3-9] However, a number of state and national administrative data sets reveal variable effects of volume on outcome after AAA repair.[3-9] Hospital volume is not the only important provider-level variable that affects outcome. Other provider characteristics, such as surgical specialty and individual surgeon volume, may also have a major influence on quality of care.[6,13,14] The objective of the current study was to determine the relative importance of surgical specialization, hospital volume, and surgeon volume on outcome after AAA repair.

METHODS

Data source. Information for 3912 patients undergoing AAA repair was abstracted from the Nationwide Inpatient Sample (NIS), a 20% stratified random sample of all hospital discharges in the United States. This database is maintained by the Agency for Health Care Research and Quality as part of the Healthcare Cost and Utilization Project.[15] The representative nature of the database is ensured by stratifying by geographic region, hospital bed size, teaching status, urban versus rural location, and hospital ownership. Data for each year includes information on approximately 7 million unique hospitalizations; sampling is conducted at the hospital level, and 100% of each hospital's discharges are included in the sample. Data for the current study were derived from the 1997 version of the NIS. During this period 536 hospitals in 22 states were identified in which AAA repair was performed. Patients

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were included if they were discharged from these hospitals with both a procedure code and a diagnostic code for AAA repair. Those patients with an *International classification of diseases*, ninth revision, Clinical modification (ICD-9-CM) primary procedure code for resection of abdominal aorta with replacement (ICD-9-CM 3844) or aortoiliac bypass (ICD-9-CM 3925)[16] were initially selected. In addition, a primary diagnostic code for AAA without mention of rupture (ICD-9-CM 4414) was necessary for inclusion in the data sample. Data for patients with a diagnostic code for ruptured AAA (ICD-9-CM 4413) were excluded from the analysis. Secondary ICD-9-CM diagnostic codes were abstracted to ascertain the presence of 10 common comorbid diseases.[17,18] Data for all patients included age, gender, race, nature of admission, in-hospital death, and length of stay (LOS).

Data analysis was limited to data for those patients with surgeon identifiers included in the NIS data set, which accounted for almost 60% of total AAA repairs performed during the single year of the study. The extent to which individual surgeon information is available depends on the policy of the state contributing data. Certain states do not provide surgeon-level information, to ensure confidentiality. Other states provide surgeon identifiers for all hospitals and all discharges from a given hospital. The surgeon identifiers are specific for the database, not the hospital. Thus, for surgeons who operate in multiple hospitals, total volume includes procedures performed at all hospitals included in the NIS dataset. Because the NIS does not include all hospitals in a given geographic area, some surgeons who operate at multiple hospitals may be misclassified as low-volume surgeons (LVSs) when in truth they are high-volume surgeons (HVSs). Such misclassification will bias the results toward the null hypothesis (no difference between HVSs and LVSs) and should have minimal effect on the analysis.

Outcome measurement. The primary outcome studied was in-hospital mortality. Adjusted analyses were performed that accounted for patient differences in demographic data (age, gender, race), 10 comorbid diseases, nature of admission (elective, urgent, emergent), and type of surgical procedure (ICD-9-CM 4414 vs ICD-9-CM 3925). The modification by Romano et al[17] of the comorbidity score of Charlson et al[18] was used with ICD-9-CM codes from an index hospitalization to account for comorbid disease in patient risk adjustments. Each comorbid disease was coded as a dichotomous variable and individually entered into the multivariate model.

Provider variables. The number of procedures performed at each hospital was calculated by using an anonymous Healthcare Cost and Utilization Project hospital identification number. The threshold for high-volume hospitals (HVH; >35/y) and HVS (>10/y) was taken as the median (50th percentile) number of procedures performed per year. These volume thresholds were chosen a priori to avert introduction of bias, and such methods are generally accepted for analysis of volume to outcome.[3-9] Further, these thresholds are consistent with recent population-based studies and hospital volume thresholds proposed in certain current health policy initiatives.[3-9,11] To determine surgeon specialization, all primary procedure ICD-9-CM codes for each surgeon for the year of study were obtained. For each unique surgeon identifier, these procedures were clustered into three practice types on the basis of specific codes: cardiac surgery (ICD-9-CM 3500-3799), general surgery (ICD-9-CM 0600-0899, 4000-5999, 8500-8799), and vascular surgery (ICD-9-CM 3800-3999, 8400-8499).

The percentage of each individual surgeon's practice dedicated to each specialty was then determined. Cardiac surgeons (n = 210) were defined as those whose practice included more than 20% cardiac procedures. Varying the cardiac surgeon threshold from 5% to 50% had no effect on number of cardiac surgeons, because most cardiac surgeons dedicate most of their practice to heart operations. The effect of specialization in vascular surgery was determined for three thresholds: more than 25%, more than 50%, and more than 75% vascular procedures. In subsequent analyses in the current study, vascular surgeons (n = 121) were defined as having performed more than 75% vascular procedures. All other surgeons were defined as general surgeons (n = 548). This method of specialty profiling was validated by confirming the number of index procedures performed by surgeons of each specialty (Table I).

Statistical analysis. Univariate comparisons of surgical specialty, hospital volume, surgeon volume, and patient characteristics with outcome variables were performed using the appropriate test, on the basis of type of data. Specifically, the χ^2 test (for two dichotomous or categorical variables), Wilcoxon rank sum test (for nonparametric continuous and dichotomous variables), and Student *t* test (for parametric continuous and dichotomous variables) were used for univariate analysis. Multiple logistic regression of in-hospital mortality was used to test the relative importance of surgeon specialty, hospital volume, and surgeon volume, after adjusting for potentially confounding patient case-mix variables. Hospital-level clustering was performed to account for the nonindependence of observations within the same center. Variables entered into the risk-adjusted model included age, gender, race, nature of admission, comorbidity index, hospital volume, surgeon volume, and surgeon specialty. The degree of colinearity among provider-level variables did not preclude inclusion of all three in the multivariate analysis. In addition, several stratified multivariate analyses were performed to demonstrate stability of the model with all three variables. The multivariate model of mortality was tested for goodness of fit according to the Hosmer-Lemeshow method, and the area under the receiver operating characteristic curve was calculated. Any patient characteristic with $P < .1$ in the univariate analysis was included in the multivariate analysis. $P < .05$ was considered statistically significant. STATA version 7.0 (Stata Corp, College Station, Tex) was used for all statistical analyses.

Table I. Characteristics of and number of specialty index cases for surgeons performing AAA repair

Characteristic	Vascular surgeons (n = 121) n	%	Cardiac surgeons (n = 210) n	%	General surgeons (n = 548) n	%
Hospital volume*						
≥35	46	38	83	40	137	25
<35	64	53	111	53	393	72
Operates at both	11	9	16	8	18	3
Surgeon volume*						
≥10	40	33	28	13	33	6
<10	81	67	182	87	515	94
	Median	IQR	Median	IQR	Median	IQR
AAA repair*	5	2-13	2	1-6	2	1-4
Index cases						
CABG	0	0-0	53	4-116	0	0-0
Valve procedure	0	0-0	9	0-23	0	0-0
Lung resection	0	0-0	3	0-10	0	0-1
Lung biopsy	0	0-0	1	0-2	0	0-0
Carotid endarterectomy	30	9-52	7	2-21	6	1-15
Lower extremity bypass grafting	22	9-39	2	0-9	5	1-13
Cholecystectomy	0	0-0	0	0-0	11	3-22
Hernia repair	0	0-0	0	0-0	3	1-7
Colon resection	0	0-0	0	0-0	7	2-14
Appendectomy	0	0-0	0	0-0	5	1-10

AAA, Abdominal aortic aneurysm; *CABG,* coronary artery bypass grafting; *IQR,* interquartile range.
*$P < .05$, χ^2 test or Wilcoxon rank sum test.

Table II. Characteristics of patients undergoing abdominal aortic aneurysm repair by vascular, cardiac, and general surgeons

Characteristic	Vascular surgeons (n = 1065) n	%	Cardiac surgeons (n = 912) n	%	General surgeons (n = 1935) n	%
Age (y; mean ± SD)	72 ± 8		72 ± 8		72 ± 8	
Female gender	217	20	174	19	417	22
Nonwhite race	70	7	58	7	158	8
Aortoiliac repair	93	9	61	7	162	8
Emergent admission*	94	9	83	9	240	12
Comorbidity index†						
1	634	60	535	59	1091	56
2	334	31	308	34	668	34
≥3	97	9	69	8	176	9

*$P <. 05$, χ^2 test.
†Romano-Charlson comorbidity index.

RESULTS

Surgeon characteristics. Vascular surgeons (38%) and cardiac surgeons (40%) were more likely to operate at high-volume hospitals (HVHs) than were general surgeons (25%; $P < .001$; Table I). Vascular surgeons (33%) were more likely to be HVSs than both cardiac surgeons (13%) and general surgeons (6%; $P < .001$). The accuracy of the surgical specialty determination strategy was confirmed by the quantity of index cases performed by each group (Table I). In this nationally representative sample of hospitals, general surgeons performed 50% of AAA repairs (n = 1935), vascular surgeons performed 27% (n = 1065) of AAA repairs, and cardiac surgeons performed 23% (n = 912) of AAA repairs.

Patient characteristics. Patients were similar across all three surgeon specialty groups with respect to demographic data and comorbid diseases (Table II). However, patients undergoing surgery by general surgeons (12%) were more likely to be admitted emergently than was the case with patients of cardiac and vascular surgeons (9%; $P = .002$). Patients at HVHs and low-volume hospitals (LVHs) were similar with respect to other demographic characteristics and degree of comorbid disease (Table II).

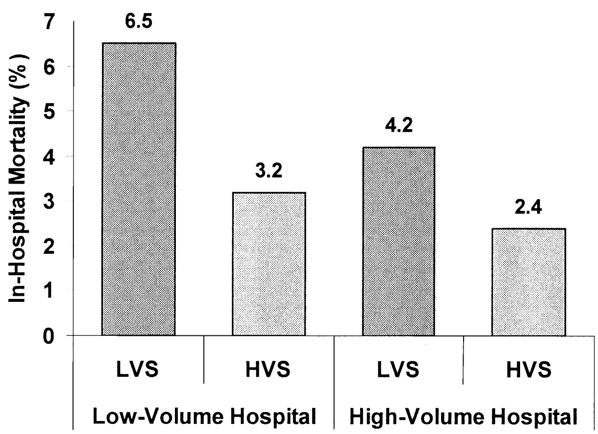

Fig 1. In-hospital mortality for high-volume surgeons and low-volume surgeons at high-volume hospitals *(HVH)* and low-volume hospitals *(LVH)* after abdominal aortic aneurysm repair in the United States. High-volume surgeons (*HVS*) are associated with significantly lower mortality than low-volume surgeons *(LVS)* at both HVH and LVH ($P < .001$).

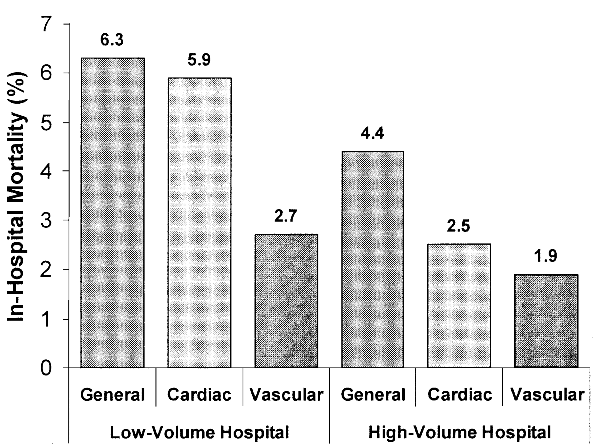

Fig 2. In-hospital mortality according to surgeon specialty at high-volume hospitals and low-volume hospitals in the United States. Vascular specialization is associated with significantly lower mortality rate compared with general surgeons at both high-volume and low-volume hospitals ($P < .05$). In addition, vascular specialization is associated with lower mortality compared with general surgeons at high-volume hospitals ($P < .05$).

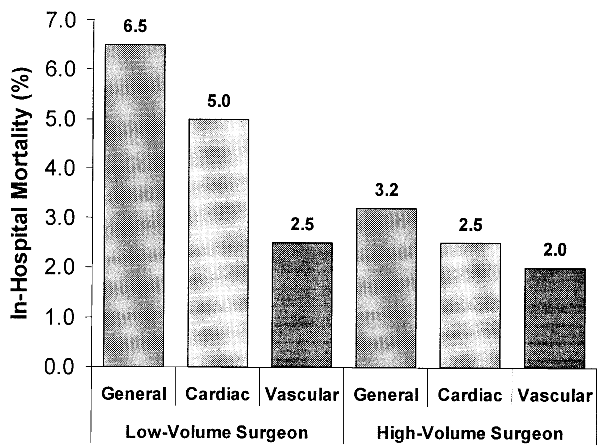

Fig 3. In-hospital mortality according to surgeon specialty and high and low individual surgeon volume. Vascular specialization is associated with significantly lower mortality rate compared with general surgeons for both high-volume surgeons and low-volume surgeons ($P < .05$).

In-hospital mortality. Overall in-hospital mortality rate for intact AAA repair was 4.2%. Mortality varied across surgical specialty, with vascular surgeons (2.2%) having significantly lower mortality rates than both cardiac (4.0%) and general surgeons (5.5%; $P < .001$). Hospital volume and surgeon volume were independent predictors of mortality, but had an additive effect. For HVSs operating in HVHs, mortality rate was 2.4% compared with 6.4% for LVSs operating in LVHs (Fig 1). Surgical specialty was an independent predictor of mortality even after stratifying by both hospital volume (Fig 2) and individual surgeon volume (Fig 3). HVHs had mortality of 3.0% compared with 5.5% at LVHs ($P < .001$). HVSs had mortality of 2.5% after AAA repair compared with 5.6% mortality for patients treated by LVSs ($P < .001$). Surgeons whose practices included greater than 75% vascular procedures had much lower mortality (2.2%) compared with those who performed less than 75% but more than 50% vascular procedures (3.2%) and less than 50% but more than 25% vascular procedures (4.1%; $P < .05$).

In the risk-adjusted analyses, surgical specialization, HVH, and HVS were all independently associated with lower risk for in-hospital death. AAA repair by general surgeons was associated with 76% (95% confidence interval [CI], 10%-190%; $P = .02$) increased risk for death compared with vascular surgeons, although no significant differences were found between cardiac and vascular surgeons (Table III). The logistic regression model was not rejected after goodness-of-fit testing ($\chi^2 = 1.67$; $P = .98$), and area under the ROC curve was 0.71. Patients undergoing AAA repair at an HVH had 30% reduction in risk for death (95% CI, 2%-51%; $P < .05$), and surgery by an HVS was associated with 40% reduction in mortality (95% CI, 12%-60%; $P = .01$). In a second multivariate analysis that included only elective AAA repairs, similar differences in mortality between general and vascular surgeons were found.

DISCUSSION

Conventional AAA repair is a complex surgical procedure performed in a variety of practice settings across the United States, and the quality of surgical care is not uniform. Lower mortality with a number of procedures has been associated with greater annual hospital surgical volume. Current health policy initiatives support referral of several complex procedures to high-volume centers on the

Table III. Multivariate analysis of in-hospital mortality after abdominal aortic aneurysm repair

Independent variable	*In-hospital mortality* OR	*(95% CI)*	*P*
Age >65 y	4.46	2.2-9.2	<.001
Emergent admission	3.22	2.2-4.7	<.001
Female gender	1.47	1.0-2.0	.05
General vs vascular surgeon	1.76	1.1-2.9	.02
Cardiac vs vascular surgeon	1.47	0.85-2.6	.17
High-volume hospital*	0.70	0.49-0.98	<.05
High-volume surgeon†	0.60	0.40-0.88	.01

OR, Odds ratio; *CI,* confidence interval.

*High-volume hospital (>35 cases per year) compared with low-volume hospital.

†High-volume surgeon (>10 cases per year) compared with low-volume surgeon.

basis of minimum volume standards.[9-11] However, such policy does not take into account differences in outcome attributable to surgical specialty or individual surgeon operative volume. The current study provides evidence that if selective referral is to occur it must take into account both of these other provider-level variables if the highest quality care is to be provided to the patient.

Previous population-based analyses suggest a variable relation between surgeon specialty, provider volume, and outcome of AAA repair. Pearce et al[6] observed a 24% lower risk for death or complications when AAA repair was performed by surgeons with American Board of Surgery Certificate of Added Qualifications in Vascular Surgery. In this study, which used the Florida hospital discharge database, a significant independent relationship was found between increasing hospital and surgeon volume and lower mortality.[6] Tu et al[13] observed 62% increased risk for mortality with AAA repair performed by general surgeons compared with vascular surgeons. Similar to our findings, no differences in outcome of AAA repair were found between cardiac surgeons and vascular surgeons. Further, in their study low surgeon volume (<5 cases per year) was associated with 83% increased risk for death. Their study used Canadian Institute for Health Information hospital discharge data linked to the Ontario Registered Patients Database to calculate risk-adjusted 30-day mortality for AAA repair.[13]

The most comprehensive analysis of provider volume and surgeon specialty has been reported in the *Dartmouth Atlas of Vascular Health Care.*[19] This work documented that LVSs (<4 per year) had a mortality rate of 7.9% compared with 4.0% for HVSs (>10 per year). Mortality rate for vascular surgeons (4.4%) and cardiac surgeons (5.4%) was lower than that for general surgeons (7.3%). Overall AAA repair mortality rates reported in the *Dartmouth Atlas* are higher than for a representative sample of the United States because its data are derived from Medicare patients, thus excluding patients younger than 65 years. With our method of specialty determination, 50% of procedures were performed by general surgeons, 27% by vascular surgeons, and 23% by cardiac surgeons. In the analysis of the effect of surgeon specialty on outcome conducted by Tu et al[13] in Ontario, 75.1% of AAA repairs were performed by 63 vascular surgeons, 20.3% by 53 general surgeons, and 4.6% by 14 cardiac surgeons. In contrast to the high proportion of AAA repairs performed by certified vascular surgeons in Ontario, in the study by Pearce et al,[6] using the discharge database in Florida, only 18% of AAA repair procedures were performed by a surgeon with vascular certification. Overall, there are wide geographic variations in proportion of AAA repairs performed by general surgeons versus vascular surgeons. The analysis provided by the *Dartmouth Atlas* documents marked variation in surgeon specialty type performing AAA repair among the 306 hospital referral regions in the United States. For example, in nine regions 0% of AAA repairs were performed by vascular surgeons, compared with 92% in Greensboro, NC. Further, in seven regions 0% of AAA repairs were performed by general surgeons, compared with 85% in Green Bay, Wis.

Surgeon specialty and provider volume are only surrogates for quality of health care. An alternative to relying on these proxies is to directly measure and compare risk-adjusted outcome between medical centers. The National Surgical Quality Improvement Project (NSQIP) within the Veterans Affairs Hospital System provides an example of how such a large-scale quality improvement project can be effective.[20] Since the inception of the NSQIP, there has been a 27% decline in risk-adjusted 30-day mortality and a 45% decline in 30-day morbidity in Veterans Administration (VA) medical centers.[20] Currently the NSQIP method is being further expanded to 14 private sector medical centers to further document the utility of such a quality improvement tool outside the VA system. Such direct measurement of outcomes to determine quality is appealing, although there are several limitations to such an approach. First, not all medical centers have the resources to make the changes necessary to improve quality. In addition, certain technologies may be associated with superior outcome, and, inasmuch as they represent large capital investment, many medical centers may not be able to acquire them. Another limitation with direct measurement of outcome is relying on the use of a summary quality measure for all surgical services at a given hospital. Few surgical procedures are performed frequently enough that precise estimates of mortality and morbidity can be generated for a single hospital.

The health policy implications of our findings are twofold. First, patient outcome is better at an HVH, with an HVS or a vascular surgeon, compared with an LVH, with an LVS or non–vascular surgeon. Second, patients are best served by a high-volume vascular surgeon. However, only 5% of surgeons currently performing AAA repair fit that profile. Patients and health care payers are responsible for choosing providers of surgical services. Our findings suggest that the proportion of AAA repairs performed by vascular surgeons should increase, which in turn will increase the number of high-volume vascular surgeons. Such a change in referral patterns would effectively reduce mortality associated with AAA repair in the United States, albeit at a probable cost of convenience to patients and their families.

Most studies of the effect of volume on outcome, using state or national administrative data sets, are subject to several well-known limitations, the most important being lack of clinical or physiologic data for risk adjustment.[21] However, there is no plausible basis on which to assume that patients undergoing surgery at LVHs are sicker than those treated at HVHs. In our analysis, adjustment was made for demographic data, nature of admission, and comorbid disease. Several of these factors were predictive of mortality, but none accounted for the differences between provider-level variables studied. Another limitation, related specifically to NIS data, is that not all hospitals in a given area were selected for inclusion in the sample. In designing the current study, we carefully considered the effect of incomplete surgeon identifiers on our data analysis. The main effect of this issue is that some HVSs will be misclassified as LVSs, but no LVSs will be misclassified as HVSs. Therefore the result of any misclassification will tend to bias the results toward the null hypothesis (no difference between HVS and LVS). Since there was an independent effect of surgeon volume on outcome, it is clear that correction of any misclassification would make the effect larger. Given these considerations, we believe the results of our analysis are valid and provide useful information.

The results of the current study have important implications. First, health policy that supports the selective referral of patients undergoing AAA repair to HVHs must consider surgical specialization and individual surgeon volume. Second, the specific processes of care involved in AAA repair at HVHs and by HVSs or vascular surgeons should be studied and used to guide quality improvement efforts for those hospitals and surgeons associated with poor surgical outcome.

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